International Journal of Educational
Science and Research (IJESR)
ISSN(P): 2249-6947; ISSN(E): 2249-8052
Vol. 5, Issue 5, Oct 2015, 43-52

PATTERN ANALYSIS OF BIOLOGICAL CONCEPT VISUALIZATION FOR SCIENCE GIFTED STUDENTS

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ABSTRACT

The study aims to show the positive role of concept visualization of complex scientific information in science learning, particularly life science, and identify the possible correlation between the depth of scientific knowledge and its level of concept visualization. A biological concept visualization workshop has been conducted with secondary science-gifted learners as a part of a creative research program for three consecutive years. The visualization outcome is categorized and analyzed based on students' biological knowledge, mainly their biology grades. Pattern analysis of visualization of high-level-grade groups shows students' focus on biological contents while intermediate-level students stress visualization itself. The low-level students perform with basic drawings of typical biological subjects. The survey shows the positive role of concept visualization for biology learning regardless of students' level of biological knowledge. The study suggests a correlation between knowledge content and concept visualization and new perspectives of visualization as a learning tool for life science.

KEYWORDS: Visualization, Pattern Analysis, Art and Science, Creative and Critical Thinking

1. INTRODUCTION

Visualizing scientific findings and scientific contents is a very significant part in science communication and understanding (Gilbert, 2005; Vavra et al., 2011). Biology, particularly, includes visual contents more than other academic fields. From visualization of organic forms in natural history (Haeckel, 2008), to visualization of complex gene regulation in molecular biology(Jacob and Monod, 1961;Takayama, 2005), visual contents are present in various forms in various

biological domains (Takayama, 2005). In recent days, with boundaries of science and art growing indefinite, the differences between biological visualization and artistic creation have become less and less clear (Kemp, 2006). This inclination has arisen owing to the imaginative visualization of scientific concrete forms (Ameisen and Brohard, 2007, Kemp 2001).

Currently, visualization in science combined with computer science has become immensely refined and developed into data visualization to present the meaning of big data. Visualization, however, contains multiple meanings (information visualization, data visualization, etc.) and various functions (summarizing, synthesizing, communicating, integrating knowledge, etc.) (Gilbert 2005, Vavra et al., 2011). The present study uses the term visualization to mean visual representation used to understand scientific knowledge, or occasionally to mean illustration and its function of presenting abstract ideas and synthetic knowledge in biological texts.

BACKGROUND

The present study analyzes science-gifted students' task results from visualization of biological knowledge for three consecutive years. The study aims to find the relations between knowledge and the level of visualization through pattern analysis identifying different characteristics of three groups labelled by their biological knowledge, interests and talents. Furthermore the educational value of visualization as a science teaching and learning tool is examined. The following research questions were posed to analyze the relationships between knowledge and visualization and evaluate the value of visualization in science education.

Question 1: Does learners' biological knowledge have an effect on their level of visualization tasking?

Question 2: Does learners' visualization have an effect on their understanding of biological concepts?

METHOD

Context

As the most renowned and leading institute for math and science gifted education in Korea, Korea Science Academy of KAIST has partnered with the Korean government to develop optimal education programs for gifted students. Thus, KSA is on the leading edge of trends in gifted-student pedagogy. Wrapping up the required national high school

curriculum within the first academic year, KSA students continue two more years with tertiary level subjects and research projects. The study was conducted in LAB(Literature, Art, Biology) project, a course of KSA's Creative Research Program, designed to implement the latest educational research, which supports the idea that multi-disciplinary contents can enhance creative and critical thinking of science-gifted students(Kang & Kim, 2014). LAB project was designed to implement a 12-week, 150-minute class per week, creative research education program for 10^{th} grade science-gifted students. The course combines artistic and literary work with selected biological subjects and is topic-based, examining a range of issues reviewed from each perspective of literature, art and science. Visualization, the core part of the present study, is a main workshop in the stage of connection carried out for two weeks. The visualization workshop results from 39 students for three years have been gathered and analyzed for the present study.

Procedure

Students were introduced to bio art, literary techniques and elements, different types of drawing samples, and calligrams to broaden their perspectives on inter-disciplinary studies. Afterwards, special lectures titled as biology/art vs. art/biology accompanied the explanation of visual contents and various examples of visualization. Then students were asked to visualize biological contents including conceptual entities through the processes of inference, deduction, intuitive reasoning, or through their perception of relations and patterns. They selected their own biological items and made notes about reasons and explanation of their choices. Then students visualized their biological items using their own choices of artistic techniques like manga, cartoon, calligram, etc. The workshop was finalized by presentation and feedback from lecturers and peers.

Data Analysis

All the students who participated in the program for three different years were divided into three groups based on their biological knowledge and interests decided by their biology grades at the end of each semester. The high-level-grade group A has the command of understanding university-level biology textbooks and A level grades. The second group B falls into the category B grades and has a decent level of high school biology understanding while the third group C has lower than B grades and little interest in biology. Pattern analyses of different characteristics of students in each group

were conducted to find the relations of knowledge and visualization. A survey analysis followed the end of the workshop to evaluate the effectiveness and value of visualization as a life science learning tool.

RESULTS AND DISCUSSIONS

Categorization

Overall, students express various biological topics using literary motifs and artistic skills and genres such as cartooning, painting, drawing and calligraming. The detailed observation, however, reveals that the level of visualization is various from mere repetition of contents from textbooks to exhibition of complex knowledge with the students' own critical view in one illustration. The noticeable part is that the low-grade group showed the tendency of summarizing and repeating existing facts while the high grade group demonstrated the ability of conveying meaningful scientific messages through broad knowledge and creating synthetic critical ideas. The characteristics of visualization based on biological knowledge of each group are presented in table 1.

Table 1: Characteristics of visualization based on biological knowledge

GROUPING	EXAMPLES OF VISUALIZATION	CHARACTERISTICS
A	Origin of life (KSK), Cell as a life(KHN), World from different animals' view(HHS), Cell membrane(PCY), Formosan deer(JJW), 3D-printing(PJW), GMO(YJW), Genetic future(IYJ), Cell garden (PCH), Illusion in the brain(JJS)	complex visualization of many biological contents, multiple meanings
B	Down syndrome with chromosome(KGW), Development of frog(KSH), Change of climate, Process of evolution(KHY), Spider chimera, Membrane Bilayer, Fatty acid, Fertilization viewed as a universe	dynamic three dimensional or detailed illustration with single theme or single idea
C	Word itself with giraffe forms, Sunflower, Chromosome, Pandora with double helix Chimera with ability(IJK), Neuron (CKH), Brain neural network(JSW)	illustration with the word itself, simple drawing with biological symbols

Pattern Analysis

Four pieces of visualization work from each group are selected and analyzed to identify the general characteristics of each group for the purpose of finding the correlations of knowledge and visualization.

Figure 1: Visualization Work from Group A

The visualization work in the top left side above (by Song K Kim) shows Genesis, chapter 1 verse 1, "*In the beginning God created the heavens and the earth*" decoded with a genetic code ATGC that encircles the earth. The biological knowledge expression reaches the level of EncryptionStones by Eduardo Kac. The other three pieces (solving food problems in the future by producing McDonald's with the use of 3D printing, bright and dark sides of GMO, various mutants from the fear of genetics) synthetically present various contents of genetic engineering. Overall the work shows negative messages related with genetic studies. It is more logical to think that students with deep biological knowledge possess critical thinking focusing on the negative sides of scientific operation, rather than that the negativity is influenced by visualization examples like Alexis Rockman's painting introduced in class.

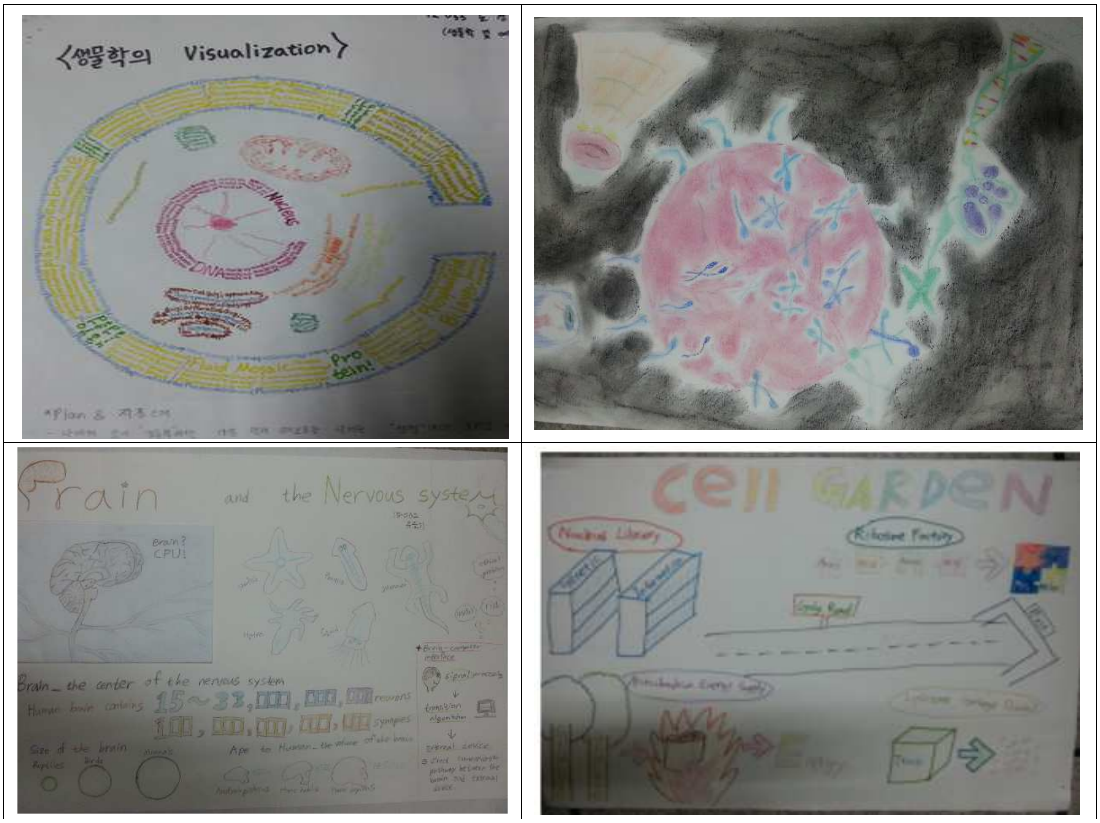

Figure 2: Visualization Work for Group B

The students in the second group focus on biological information. The work in the top left side converts abstract ideas of life to an English word, CELL, with completed details of its functions. Visualization in the top right side expresses life as the universe with an ovum illustrated as the sun and sperm, the flare of the sun trying to reach the core. The others illustrate the functions of a brain and cell based on their knowledge.

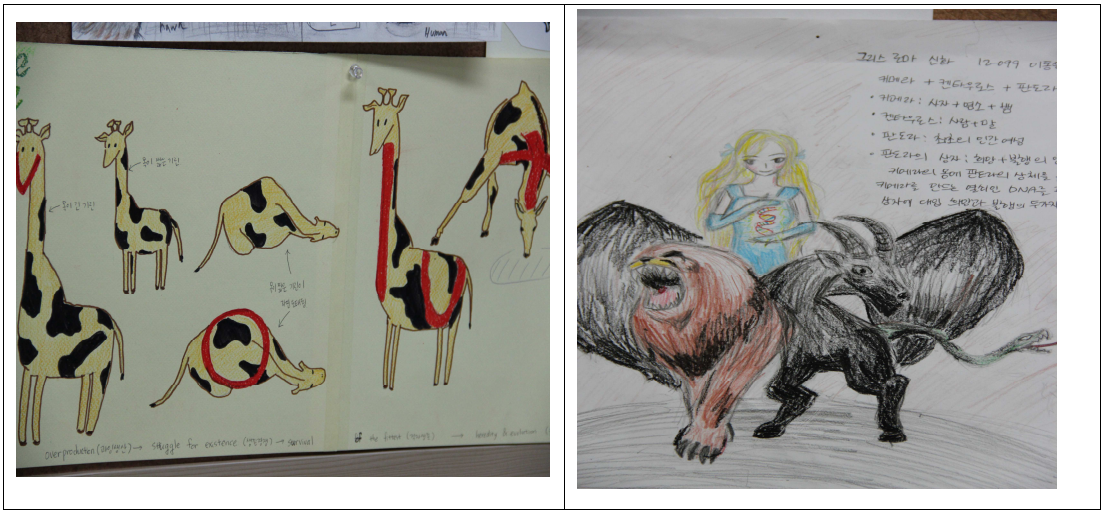

Figure 3: Visualization Work for Group C

The selected pieces of the students in the third group C include the expression of evolution by painting giraffes for evolutionary processes, drawing Chimera appearing from DNA, drawing a diagram of brain circuits by lines, and illustrating the shapes of neurons. The visualization task is focused more on illustration than scientific contents, targeted on single biological fact or content.

Survey Analysis

Questionnaires were conducted at the end of the project and analyzed to establish relevant findings for the second research question, the effectiveness of visualization as a life science learning tool. The open-ended comments showed that visualization helped enhance understanding of biological contents regardless of the level of students' knowledge. For the time of the workshop they were able to contemplate their own ideas in addition to biological contents. Moreover, students responded with highly positive feedback on the process and method of the visualization workshop. They were particularly inspired by the presentations of other students and noticed that they acquired new perspectives on the same biological contents. Students commented they shared increased concentration and motivation in a fun and enjoyable environment which made learning stay in the long term memory.

CONCLUSION AND PERSPECTIVES

Based on the grouping by final letter grades of biology subjects, the complexity and synthesis of visualization in each group are examined to find the relations of biological knowledge and visual representation. The pattern analyses show

that higher achievers in biology grades attempt to express biological contents from complex and relation-pursuing perspectives while low-grade students prefer delivering simple biological knowledge in visual forms. The high-level students create elaborate critical messages regarding latest biological agendas in addition to complex and diverse meanings based on biological contents. The mid-level students have the tendency to focus on covering a large amount of biological contents without their own views. The low-level students simply illustrate biological contents or repeat illustrations from textbooks. On the other hand, visualization work which does not fall into generalized features is exceptionally found in each category. There are indeed a few students in the high-level group showing simple expression of biological knowledge rather than complex messages. In the case of low-grade students, it might not be entirely correct to say that their uncomplicated work or plain repetition of the textbook is caused by their lack of knowledge. It could be the case that they simply did not like to draw or feel self-conscious about their illustration techniques. Therefore it is not completely justifiable to conclude that knowledge determines the level of visualization. However, it is worth paying attention to the tendency that the students with high biological grades generally try to convey critical negative views of latest biological agendas like genetic engineering. It needs further research to find whether their critical thinking has been developed with deeper knowledge or if they encounter more negative contents with studies.

Regarding the strengths of the visualization, students mention increased understanding and concentration, facilitation of flexible and creative thinking, application of knowledge, and lastly but not the least, creation of a fun and enjoyable learning environment. This shows the potentials of visualization experiences as a life science learning tool in terms of the variety and effectiveness. The present study is on the process of on-going implementation and with more data analyses, it is expected to provide more implications for the relationships between students' knowledge and its visual expressions and applicable references to biology education.

ACKNOWLEDGEMENTS

This work was funded by Korean Ministry of Science, ICT and Future Planning.

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